

DEC 23 1946

RB No. 3F19

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

# WARTIME REPORT

ORIGINALLY ISSUED

June 1943 as  
Restricted Bulletin 3F19

RESUME OF HINGE-MOMENT DATA FOR UNSHIELDED

HORN-BALANCED CONTROL SURFACES

By John G. Lowry

Langley Memorial Aeronautical Laboratory  
Langley Field, Va.

FOR REFERENCE



WASHINGTON

N A C A LIBRARY  
LANGLEY MEMORIAL AERONAUTICAL  
LABORATORY  
Langley Field, Va.

NACA WARTIME REPORTS are reprints of papers originally issued to provide rapid distribution of advance research results to an authorized group requiring them for the war effort. They were previously held under a security status but are now unclassified. Some of these reports were not technically edited. All have been reproduced without change in order to expedite general distribution.

## NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

## RESTRICTED BULLETIN

RÉSUMÉ OF HINGE-MOMENT DATA FOR UNSHIELDED  
HORN-BALANCED CONTROL SURFACES

By John G. Lowry

## SUMMARY

The available hinge-moment data for unshielded horn-balanced control surfaces have been summarized herein. An attempt has been made to present the data in a form that may be of some assistance in the preliminary design of horn-balanced controls.

The data indicate that an increase in stick-free stability can be obtained with a horn balance, but care must be taken to eliminate the undesirable heaviness of control forces that accompanies this increase in stick-free stability.

## INTRODUCTION

In conjunction with the control-surface investigation by the National Advisory Committee for Aeronautics, the available data on unshielded horn balances have been summarized herein. The purpose of this paper is to correlate the available data and to present them in a form that may be of some assistance in the estimation of the balance characteristics for use in the design and alteration of control surfaces with horn balances.

The data used in preparing this résumé include the results of wind-tunnel investigations by the NACA and by British experimenters and of flight tests by the NACA. The data were obtained from references 1 to 6 and from previously circulated restricted data obtained for the Bureau of Aeronautics, Navy Department.

A bibliography that gives discussions of horn balances outside the scope of this résumé is also presented.

## PARAMETERS AND SYMBOLS

- $C_h$  hinge-moment coefficient ( $H/q\bar{c}^2b$ ; British use  $H/qSc'$ , which should reduce value of  $C_h$  by less than 10 percent for surfaces presented)
- $H$  hinge moment of control surface about hinge axis; positive when moment tends to give positive deflection
- $c$  chord of control surface, measured from hinge axis to trailing edge
- $c'$  mean chord of control surface
- $\bar{c}$  root-mean-square chord of control surface
- $b$  span of control surface
- $S$  area of control surface behind hinge axis
- $B$  balance coefficient
- $$\left( \sqrt{\frac{\text{horn area} \times \text{horn mean chord}}{\text{control-surface area} \times \text{control-surface mean chord}}} \right)$$
- $C_{h\delta} = (\partial C_h / \partial \delta)_\alpha$
- $\Delta C_{h\delta}$   $C_{h\delta}$  of control surface with horn balance -  $C_{h\delta}$  of control surface without horn balance
- $C_{h\alpha} = (\partial C_h / \partial \alpha)_\delta$
- $\Delta C_{h\alpha}$   $C_{h\alpha}$  of control surface with horn balance -  $C_{h\alpha}$  of control surface without horn balance
- $\alpha$  angle of attack of control surface
- $\delta$  deflection of control surface
- $q$  free-stream dynamic pressure  $\left( \frac{1}{2} \rho V^2 \right)$
- $\rho$  mass density of air
- $V$  velocity of air stream

The subscript outside the parentheses in the definitions of  $C_{h_\delta}$  and  $C_{h_\alpha}$  indicates the variable held constant during the measurement of the parameter.

## DISCUSSION

Because most of the data used in this résumé came from British reports and the complete data were not available in many cases, it was necessary to make the correlation by using available parameters. Priestley in reference 3 presented the horn-balance data in terms of the parameter

$$\sqrt{\frac{\text{horn area} \times \text{horn mean chord}}{\text{control-surface area} \times \text{control-surface mean chord}}}$$

which is called herein the balance coefficient  $B$ . The data of reference 3, which were presented in the form of  $C_{h_\delta}$  and  $C_{h_\alpha}$ , have been replotted in the form of  $\Delta C_{h_\delta}$  and  $\Delta C_{h_\alpha}$  along with data from references 1, 2, 4 to 6, and unpublished data. It was observed from these graphs that the balance coefficient  $B$  gave a correlation, with a few exceptions, if the horns were divided according to type into two groups. Inasmuch as the horns were similar within each group, they were designated type A (fig. 1) and type B (fig. 2). The values of  $\Delta C_{h_\delta}$  and  $\Delta C_{h_\alpha}$  were plotted for control surfaces with horns of type A in figures 3 and 4 and with horns of type B in figures 5 and 6. The data for horns of type A appear to correlate very well, but the values for horns of type B show considerable scatter. Because the loads on the horn depend to some extent on the tip shape, it would be expected that some factor accounting for the tip shape would be needed for a correlation of horn balances, particularly for horns of type B. No attempt was made to determine a tip-shape factor that would improve the correlation, as no systematic variation of tip shape has been made.

The results of this correlation indicate that sufficient data are available for the preliminary design of horn-balanced control surfaces. The effectiveness of the horn balance depends on the flow over the tip of the control surface; it would therefore be advisable to make

relatively large-scale wind-tunnel tests of horn-balanced controls before the final design is completed. Appropriate efficiency factors should be applied to the wind-tunnel data to account for the nonuniform flow along the span of the control if the control surface is in the wake of undercarriages, propellers, nacelles, and so forth.

The graph of  $C_{h\alpha}$  against  $C_{h\delta}$  for horns of type A and type B (fig. 7) shows a considerable range in which an airplane equipped with a horn-balanced control will be more stable with the stick free than with the stick fixed; that is,  $C_{h\alpha}$  is positive while  $C_{h\delta}$  remains negative (reference 7). This increase in stick-free stability results from the floating of the control in such a manner as to give a returning moment if the airplane is displaced. Because the magnitude of control motion with controls free is a function of both  $C_{h\alpha}$  and  $C_{h\delta}$  it is possible, if  $C_{h\delta}$  is small and negative and  $C_{h\alpha}$  is positive, to have the returning moment large enough to displace the airplane in the opposite direction and set up a condition of continuous steady oscillations (reference 8).

The increase in stick-free stability is accompanied by an increased heaviness of the control forces. This increase in heaviness, which is a result of the positive value of  $C_{h\alpha}$  without a comparable change in the value of  $C_{h\delta}$ , may be eliminated if the value of  $C_{h\alpha}$  is kept near zero and the negative values of  $C_{h\delta}$  are reduced by a balancing tab or by some other means. Unpublished NACA flight-test data as well as theoretical consideration confirm the foregoing statement. The region in which both  $C_{h\alpha}$  and  $C_{h\delta}$  are positive (fig. 7) is of little interest as the control is overbalanced in this region.

Horn balances, in general, have proved unsatisfactory for use on ailerons because they are adversely affected by yaw. The effect of yaw on the tail surfaces should depend on the shielding effect of the fuselage, the flow over the tail surface during yaw, and other characteristics peculiar to each installation. Recent unpublished flight-test data showed that a control surface with unshielded horns of type A required a large

push force to prevent upward deflection of the elevator when the airplane was yawed. No investigation of these effects or of any possible modifications to help eliminate the adverse affect has been made.

### CONCLUSIONS

From the data presented in this résumé, it would appear that preliminary designs of horn balances can be made on the basis of the curves given herein.

The stick-free stability of any airplane can be improved to some extent by the use of horn balances, but care must be taken to eliminate any undesirable heaviness of control forces.

Langley Memorial Aeronautical Laboratory,  
National Advisory Committee for Aeronautics,  
Langley Field, Va..

### REFERENCES

1. Bradfield, F. B.: A Collection of Wind Tunnel Data on the Balancing of Controls. R. & M. No. 1420, British A.R.C., 1932.
2. Gorsky, V. P.: Aerodynamic Investigations of Tail Surfaces with Balanced and Unbalanced Elevators. Rep. No. 49, Central Aero-Hydrodynamical Inst. (Moscow), 1930, pp. 49-90.
- ③ 3. Priestley, E.: An Analysis of Model Hinge Moments on Set-Back Hinge and Horn-Balanced Controls. B.A. Dept. Note - Performance No. 10, British A.R.C. 1131 50  
Jan. 1940.
4. Sivells, James C.: Tests in the 19-Foot Pressure Tunnel of a Rectangular NACA 0012 Horizontal Tail Plane with Plain and Horn-Balanced Elevators. NACA A.R.R., Oct. 1942.
5. Harris, Thomas A.: Reduction of Hinge Moments of Airplane Control Surfaces by Tabs. Rep. No. 528, NACA, 1935.

6. Pannell, J. R., and Campbell, N. R.: The Balancing of Wing Flaps. R. & M. No. 200, British A.C.A., 1916.
7. Ames, Milton B., Jr., and Sears, Richard I.: Determination of Control-Surface Characteristics from NACA Plain-Flap and Tab Data. Rep. No. 721, NACA, 1941.
8. Greenberg, Harry, and Sternfield, Leonard: A theoretical Investigation of the Lateral Oscillations of an Airplane with Free Rudder with Special Reference to the Effect of Friction. NACA A.R.R., March 1943.

#### BIBLIOGRAPHY

- Batson, A. S.: Pressure Distribution on Wing with Fixed Balanced Aileron (Square Horn Type). R. & M. No. 709, British A.R.C., 1921.
- Diehl, Walter S.: Notes on Balanced Control Surfaces. Bur. Aero. T.N. No. 116, June 15, 1923.
- Gandy, R. W. G., Burge, C. H., and Sweeting, N. E.: Model Tests on the Elevators of the "Beaufighter." 5560 S. & C. 1308, E.P.L., Jan. 6, 1942.
- Irving, H. B., and Batson, A. S.: An Investigation of the Aerodynamic Properties of Wing Ailerons. Part IV. The Effect of Yaw on the Balance of Ailerons of the "Horn" Type. R. & M. No. 728, British A.R.C., 1922.
- Jones, R., and Williams, D. H.: Experiments on Balanced Control Surfaces for Rigid Airships. R. & M. No. 653, British A.C.A., 1921.
- Morgan, M. B.: Note on Horn Balanced Elevators. Rep. No. B.A. 1545, R.A.E., Aug. 1939.
- Pugsley, A. G., and Starkey, R. D.: The Torsional Divergence of a Horn-Balanced Control Surface. Rep. No. A.D. 3117, R.A.E., Nov. 1938.
- Relf, E. F., Bryant, L. W., Irving, H. B., Pannell, J. R., and Campbell, N. R.: Experiments on Models of Complete Aeroplanes. R. & M. No. 198, British A.C.A., 1915.
- Roché, J. A.: Study of Balanced Rudders. A.C.I.C., vol. VI, no. 586, Materiel Div., Army Air Corps, 1927.

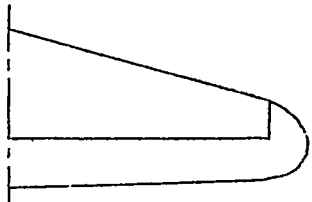
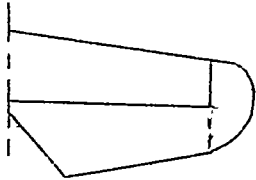
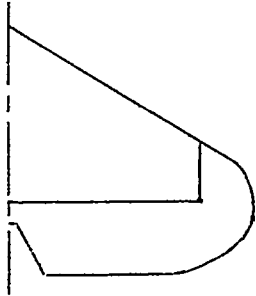

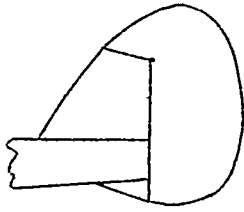
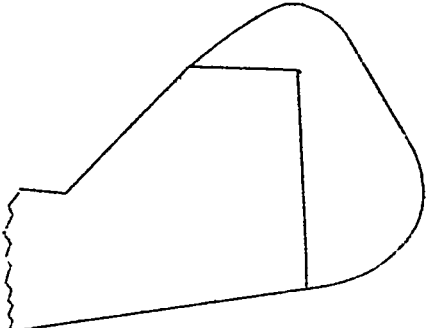
	Control surface	Symbol used on figs. 3 to 7	Fig. 1 Reference
	1	○	3
	2	▽	Unpublished
	3	□	2
	4	×	6
	5	◇	3
	6	△	3

Figure 1.- Plan forms of horn-balanced control surfaces. Type A.



NACA

	Control surface	Symbol used on figs. 3 to 7	Fig. 2 Reference
	7	▽	3
	8	△	3
	9	△	3
	10	▽	4
	11	+	5
	12	△	1
	13	▽	3

Figure 2.- Plan forms of horn-balanced control surfaces. Type B.

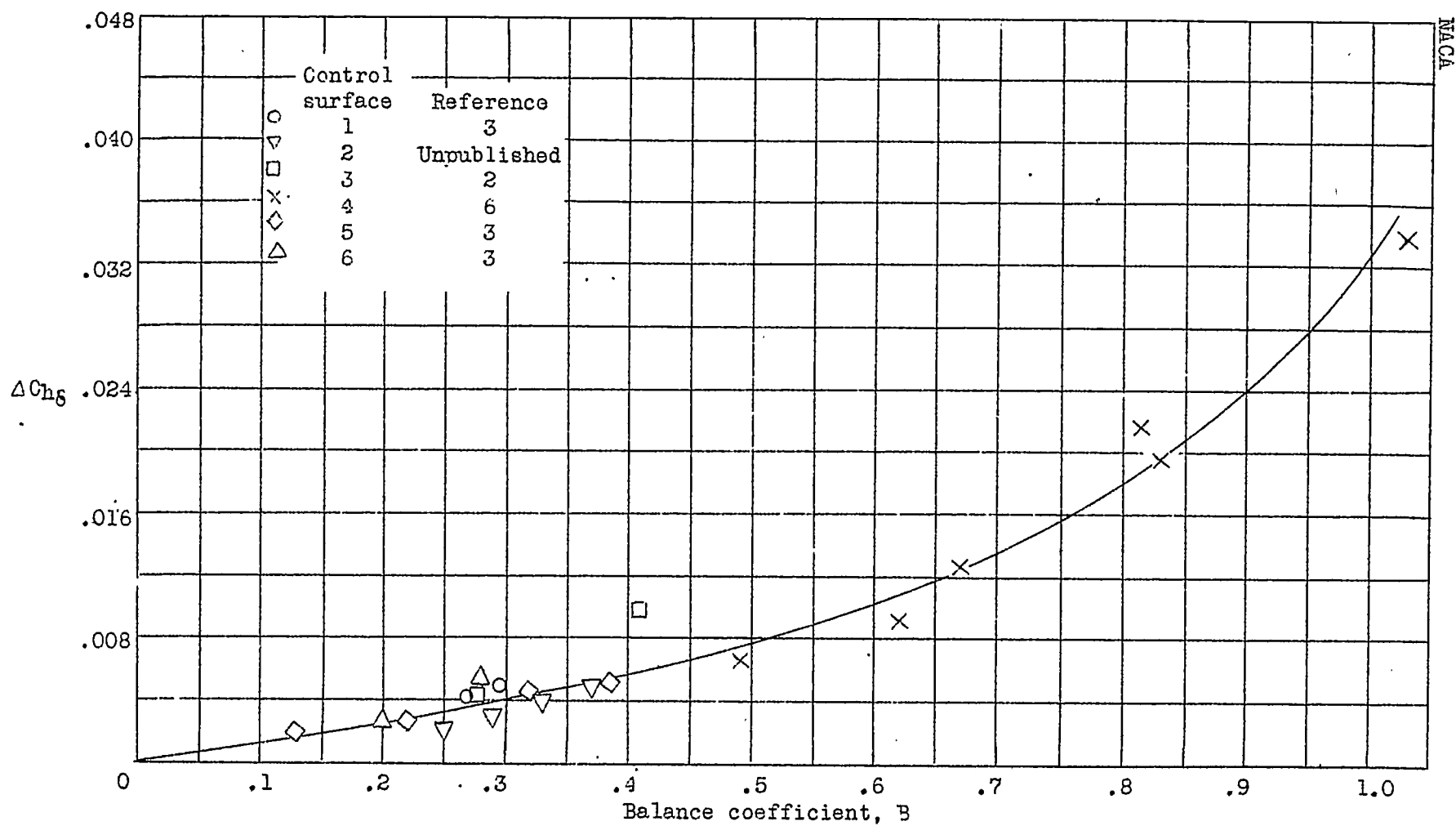


Figure 3.- Variation of incremental hinge-moment-coefficient slope  $\Delta C_{h\delta}$  with balance coefficient B.  
Horns, type A.

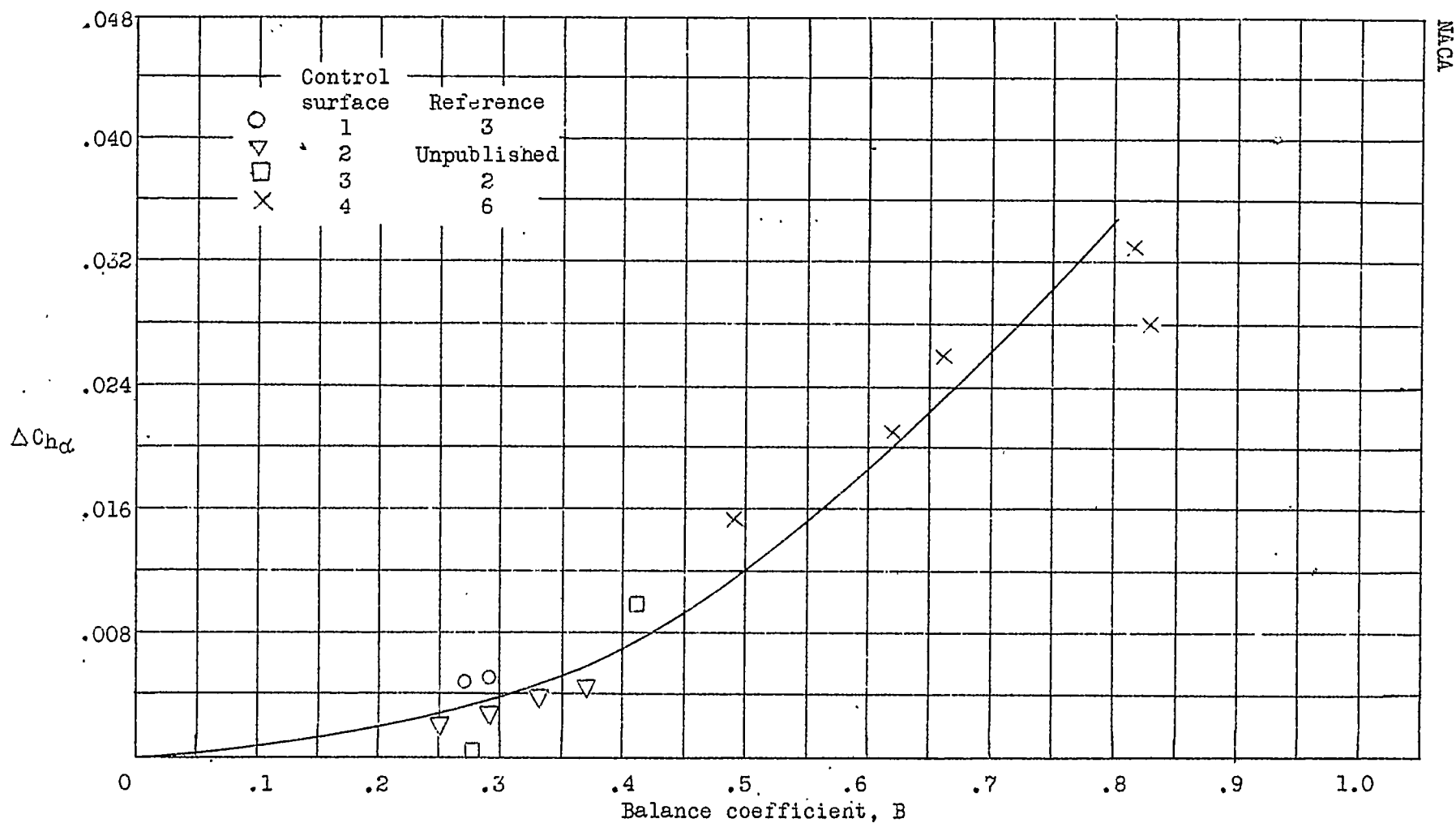


Figure 4.- Variation of incremental hinge-moment-coefficient slope  $\Delta C_{h\alpha}$  with balance coefficient  $B$ .  
Horns, type A.

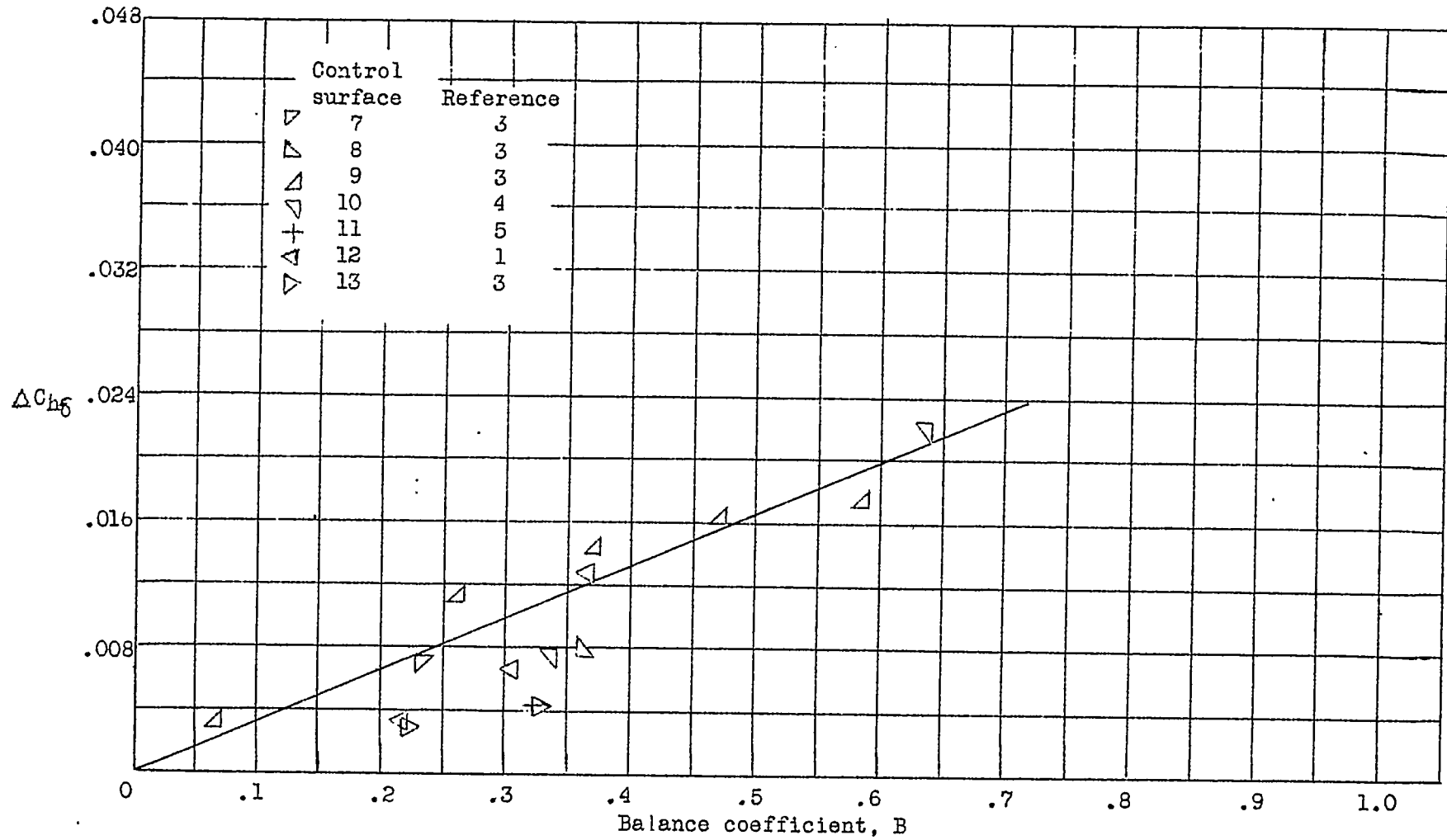


Figure 5.- Variation of incremental hinge-moment-coefficient slope  $\Delta Ch_\delta$  with balance coefficient  $B$ .  
Horns, type B.

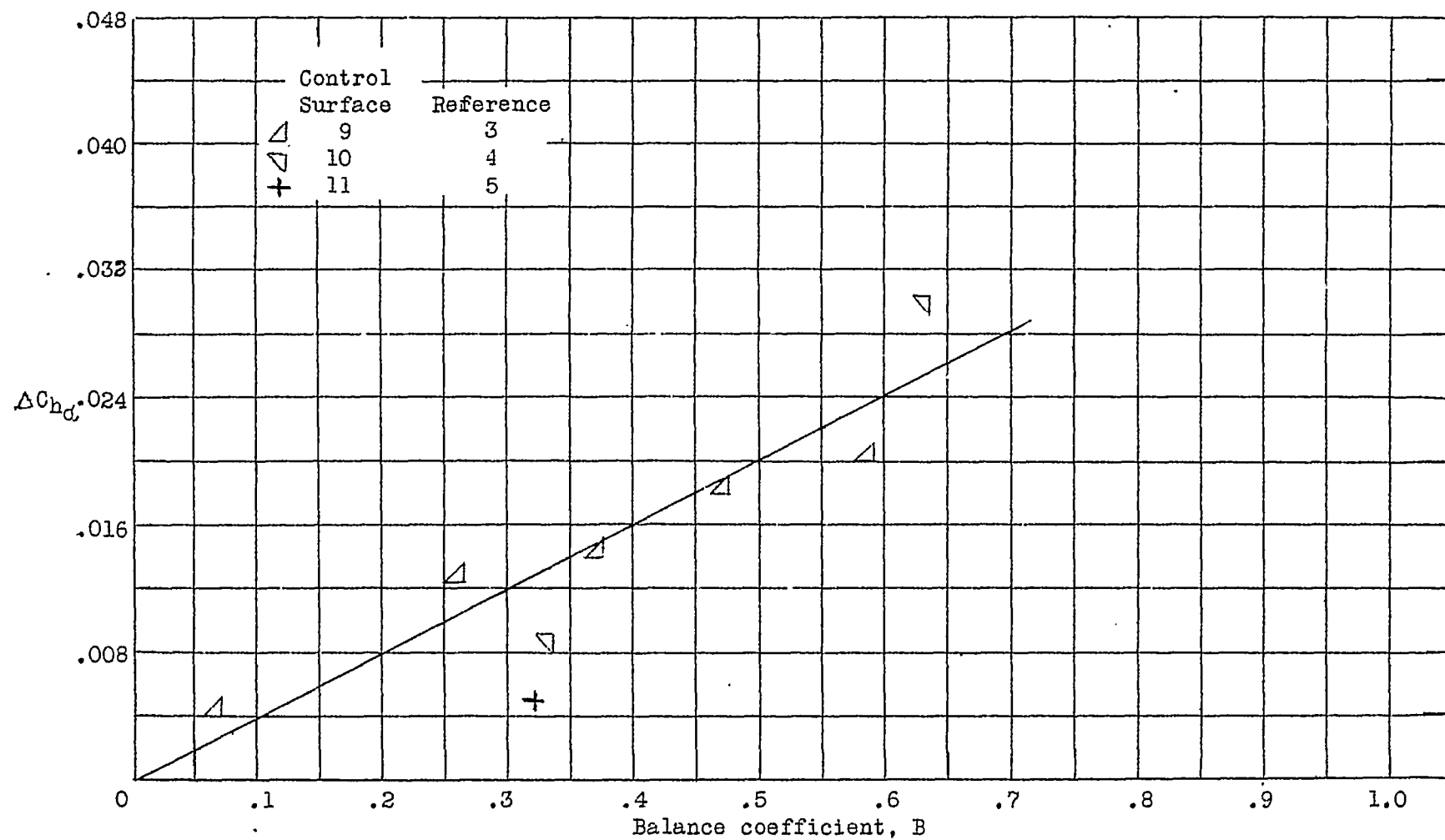


Figure 6.- Variation of incremental hinge-moment-coefficient slope  $\Delta C_{hd}$  with balance coefficient B. Horns, type B.

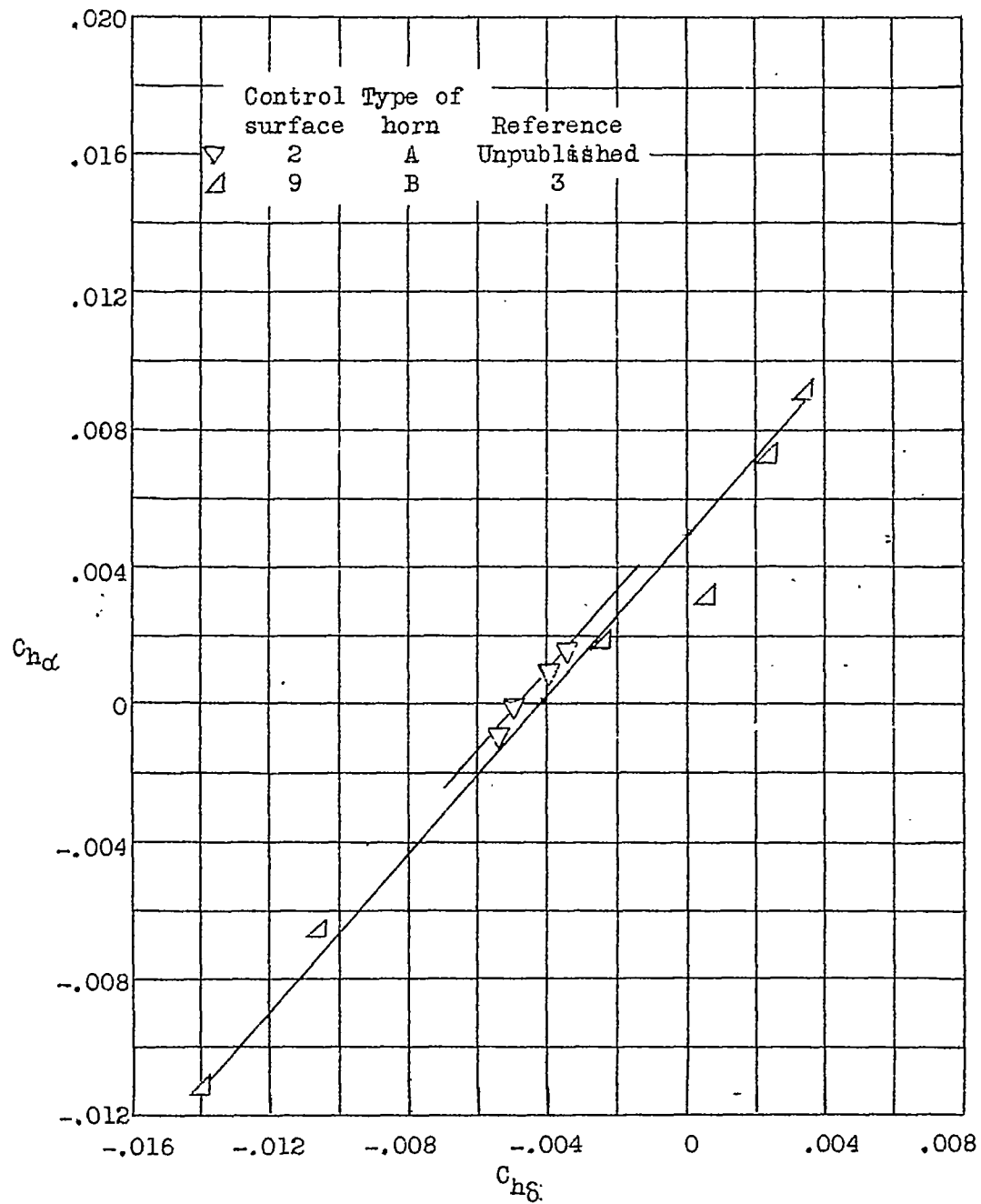


Figure 7.- Variation of  $C_{h\alpha}$  with  $C_{h\delta}$  for unshielded horn-balanced control surfaces.